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# Feeling Your Way Around: Assessing the Perceived Utility of Multi-Scale Indoor Tactile Maps

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## Abstract
Tactile maps of indoor spaces have great potential for supporting pre-journey spatial learning by blind travelers. Due to the limited resolution of tactile sensing, though, only a limited amount of spatial detail can be embossed in a map at a certain scale. We conducted a focus group with blind participants in order to obtain some insight on the perceived utility of using multiple maps at different spatial scales, and thus different level of detail, to represent the interior of a building.

## Author Keywords
Tactile maps; Spatial information access; Indoor mapping.

## CCS Concepts
•**Human-centered computing** $\rightarrow$ **Empirical studies in accessibility;** *Accessibility technologies;*

## Introduction
Access to spatial information can be vexing for people who are blind. Lacking visual input, blind individuals must rely on their own knowledge, through direct experience or otherwise, of the spatial configuration of places they are visiting. Pre-journey learning, the process of "learning a spatial environment or plan a travel route prior to actual travel" [20], is an effective way to mitigate the difficulties of independent blind travel. Multiple studies have shown that, when blind travelers are given the opportunity to '"preview" an indoor route,

for example using a tactile map [3, 7], they can follow a route more accurately and with fewer errors. Tactile maps allow a blind person to build a prior representation of the space to be traversed, in the form of an egocentric spatial image [12] or an allocentric cognitive map [16].

Creating a tactile map by hand can be time-consuming and requires specific expertise, which may be one of the reasons why tactile maps are not universally available. Automated generation of tactile maps, with data sourced form a Geographical Information System (GIS), has been implemented in projects such as TMAP [14], TMACS2 [23], Mapy [4], and On Demand Tactile Map (ODTM) [21]. All of these systems have considered outdoor environments, with symbols representing streets and other landmarks (i.e., parks, rivers, buildings, etc). Less attention has been devoted to generating maps of indoor spaces. Examples include [17], who developed digital maps from floor plan images, and [20, 2], who built 3-D maps of interiors.

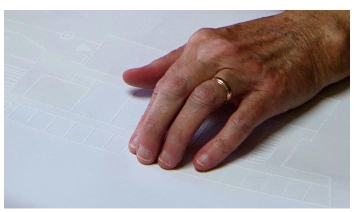

**Figure 1:** Exploring a tactile map of a building.

One very practical challenge of automatic tactile map production is that maps of indoor places in digital format are often difficult to find. Even though most buildings may have detailed CAD floor plans, what is available in most cases are only pictures of these maps in JPEG or PDF format. And even when a map is available in an appropriate format, the designer, or the algorithm tasked with converting it to a tactile form, needs to decide what level of detail should be contained at a given scale. Although this *generalization* problem is common to all types of map design [13, 15], it is a particularly relevant one, and yet relatively unexplored, in the case of tactile maps. This is because tactile sensing affords relatively low spatial resolution, which reduces the achievable density of detail reproducible in a tactile map. The average spatial tactile acuity at the index finger is of about 1.2 mm [9]; and the Braille dots must have the minimum center-to-center spacing of 2.28 mm. Hence, when representing a certain portion of space (e.g., the floor plan of a building wing) on a Braille paper sheet whose standard size is 11 by 11.5 in., the designer needs to decide which details can be part of the map, and which can be removed, lest the map become too crowded, and thus difficult to read [19]. This is usually done following "tricks of the trade" or guidelines developed by expert practitioners [5, 1].

To facilitate generation of indoor tactile maps, in prior work, we have built an online application, named Semantic Interior Mapology or SIM[1], to enable a quick generation of an indoor map in a suitable format of GeoJSON, starting from a picture of the floor plan [22]. SIM users can trace the contour of interior spaces using a simple and intuitive interface. In addition, we have developed an operational pipeline to acquire and precisely georegister space elements of interest such as appliances and furnitures. A 3-D scan of the environment is acquired using an RGB-D camera. This spatial data is then segmented into elements of interest, which are automatically registered with the GeoJSON map of the building. When desired, these elements can be represented in a map at an appropriate spatial scale. Our SIM workflow is shown in the Fig. 2.

While tools such as SIM can help encode a building's spatial layout at the desired resolution for later embossing, the generalization problem still remains: *What is the adequate scale, and thus the adequate level of detail, at which a map of a building should be embossed? Should maps be made available at different spatial scales? And if so, what is the optimal selection of scales so as to facilitate creation of a mental spatial representation without becoming confusing?* In order to get some insight into these questions, we con-

[1] Our SIM application is available at https://sim.soe.ucsc.edu

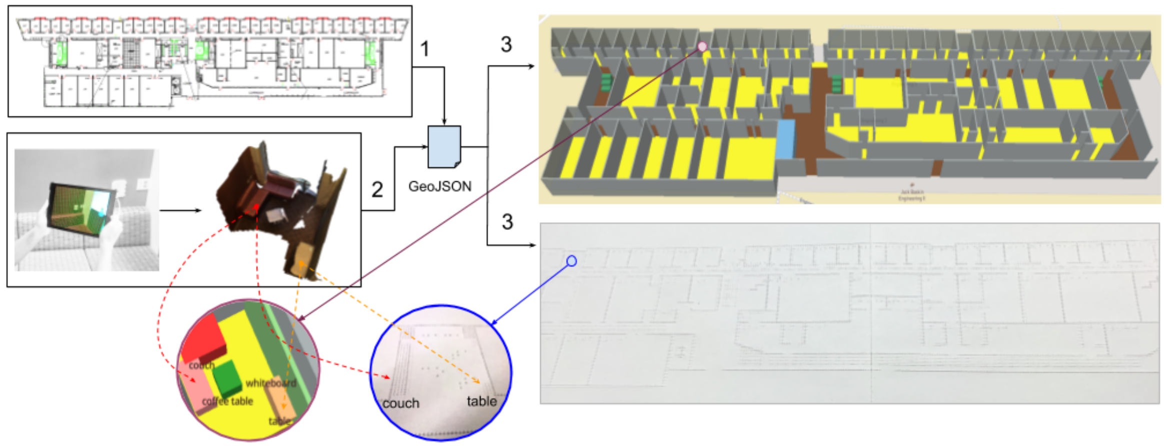


**Figure 2:** Workflow of our SIM toolbox [22]. (1) Tracing a floor plan to generate a GeoJSON representation; (2) Acquiring a 3-D mesh of a space; segmenting out and embedding elements of interest into this GeoJSON map; (3) Rendering the spatial information in different modalities; in this case, a pop-up 3-D model on OpenStreetMap and a tactile map on embossed paper.

ducted a focus group with blind participants, as discussed in the next section.

## Method

We recruited seven participants (four identified as female, three as male) with ages ranging between 23 and 70. All participants were blind, with at most some residual light perception. They were recruited from the Vista Center for the Blind and Visually Impaired in Santa Cruz, CA[2]. All of the participants considered themselves expert independent travelers. Three of them used a guide dog for mobility, while the remaining ones used a long cane.

For this focus group, we prepared multiple copies of three tactile maps, representing the same building locations at different spatial scale (Fig. 3). These maps, embossed using a ViewPlus Max Embosser, had building name and floor number positioned at the top-center. A map scale and an arrow pointing to the North direction were embossed at the top-left and top-right corners, respectively. Building names, floor numbers, and map scales were embossed in Braille. The table 1 lists the tactile symbols and patterns used to represent features and spaces in our maps. These tactile graphics were determined to be distinctively discriminable in prior studies [11, 8, 18]. We chose the following spatial scales for our maps: *structure*, *section*, and *room*.

- *Structure-level:* Due to the considered building's elongated shape, the structure-level map (Fig. 3-a) was embossed over two contiguous sheets of size 11 by 11.5 in. The other scales were embossed on a single sheet. The structure-level map displays the general

[2]https://vistacenter.org/

| | Symbol |
|---|---|
| entrance | ⊕ |
| staircase | ▤ |
| elevator | ▲⊓ |
| door | ∧ |
| fountain | ● |
| | **Pattern** |
| corridor | |
| fixture | |
| furniture | |

**Table 1:** Tactile graphics represent features and spaces at different scales. The staircase symbol was suggested in [8], while the other symbols were drawn from [11]. The texture pattern for different spaces were proposed in [18].

layout of a building, consisting of walls, offices, corridors, building entrances, staircases and elevators. A wall was embossed as a solid line; and an office is represented by an empty untextured space enclosed by at least 4 walls. Corridors are represented as textured areas. In the structure-level map, doors and office numbers are not rendered. We felt that marking doors of each office would have led to a confusing high-density pattern. Also, there was not enough room to emboss all office numbers in Braille.

- *Section-level:* This scale represents an expanded view of a specific area inside the building (Fig. 3-b). In addition to features already considered in the structure-level map, the section-level map displays office numbers, doors, and a water fountain. The office numbers were embossed at the center of each office, and doors were rendered as wedges along walls. The pointy top of a wedge represents the direction to enter the room.
- *Room-level:* In this scale, the map displays a room's interior in detail (Fig. 3-c). For our focus group, we mapped a laboratory, featuring a cluster of cubicles, a long table, two bookshelves, and a fridge. The names of all furniture items were annotated in Braille.

A copy of the maps at three scales was distributed to each participant at the beginning of the focus group. Participants were first asked to orient the maps such that the arrow pointing to the North direction was found at the top-right corner. Next, participants were asked to identify and locate several features in the maps: entrances, staircases, corridors, office spaces, office doors, office numbers, and furnitures (Fig. 4). These maps did not contain a legend with the symbols meaning; instead, participants were explained in words how each symbols was shaped. After an initial exploration, the focus group started in earnest. A number of questions

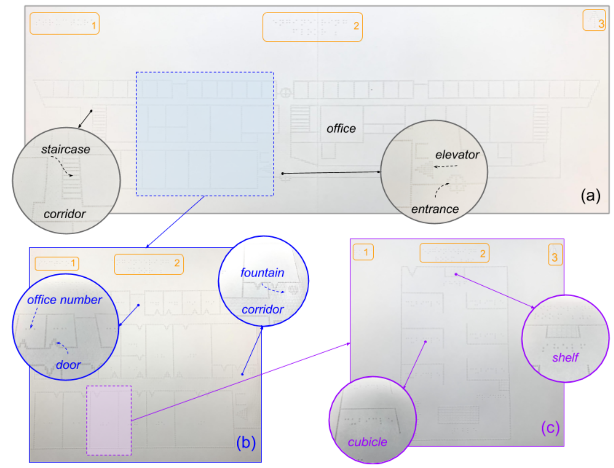


**Figure 3:** The provided tactile maps to participants in our focus group. They represent the same building at different spatial scales: (a) structure, (b) section, (c) room. The map scale, the building name, and the North direction are encoded on each map at the positions 1, 2, and 3, respectively.

were proposed, with the goal to elicit a discussion on the perceived utility of tactile maps for indoors in general, as well as of the multi-scale versions that were provided. The focus group was audio recorded for later transcription.

## Findings

The focus group transcript was analyzed independently by the two authors who also acted as the moderator and the assisted moderator at the focus group. Each investigator independently identified a list of themes and issues that emerged from the conversation. Then, the investigators met to discuss the findings and find a consensus on the set of topics used to code the relevant parts of the conversation. The resulting topics are discussed below.

**Figure 4:** Participants in our focus group were exploring the provided tactile maps at three different levels of scale.

*Perceived utility of the maps for indoor pre-journey learning*
Several participants felt that these maps would be useful, perhaps as an "add-on to the place you will like to go". A situation considered was that of a driver dropping a person in front of door B, "and you're like I wonder where I saw door B on the map. I just need to walk. Left right and I'm at the front desk." Or when visiting a medical clinic: "The more that you can do independently having that correct information". Some asked where these maps would be kept, and how they would be made available. This concern was clearly in the mind of several participants, who mentioned past negative experiences of documents in Braille that were supposed to be available, but could not be accessed.

Not surprisingly, the physical size of the maps was a concern for some participants – especially for the map spread over two sheets. Smaller is better, especially if maps were meant to be carried along in a trip. In this case, it would be preferable if they were embossed on a plastic material that could be rolled up. But even so, one would need to find a flat area to flatten the map on, which may be unpractical.

While a sense of independence was generally considered valuable, some of the participants noted that often there are people nearby who can offer help. This may reduce the perceived importance of maps, especially at the room-level scale. Interaction with sighted bystanders is not always easy, though, such as in crowded situations: "If there's a lot of other people around, I don't have a clue. There's too much input coming." Or, bystanders may sometimes be too eager to help: "If there's other people in there you know we hesitate just for a minute they're gonna be 'hey can I help you, you know and blah blah'".

*What can be learned from a map?*
One participant, who has been blind since birth, said that she felt the maps, or at least the map at largest scale, did give her a general picture of the layout, but she would not get anything "extra" from the map than if someone had just explained the scene to her (e.g. enumerating the corridors and the staircases.) This is because it was "difficult for [her] to picture a building layout from a two dimensional map". Interestingly, this participant felt that the map would be more useful post-facto – after "wander around and screw up like I screwed up a few times, I could look at a map and go 'oh that's what I did'. But I have a harder time going the other way."

Maps convey information about the size of spaces. Whether this information is easy to use when building a mental picture of a place was debated, with one participant feeling that at least the relative size of two spaces could be easily inferred from the map, while another feeling that, knowing the exact length of, say, a corridor, was not particular useful, besides going "Gosh, this is big!". Maps could be made to also contain wayfinding information to reach specific destinations, although this was not the case for the sample maps presented to this focus group. For example, a participant mentioned a frequent situation of taking an elevator, then not knowing whether to turn left or right after getting off – something she felt would be useful to have in a map.

*One or more scales?*
The need for multiple scale levels was appreciated by several participants, in particular for the first two scale factors. Some agreement emerged on the structure-level map being the most useful one, provided that it could contain room numbers, or that it could somehow be combined with the section-level map. One interesting observation was that different scale maps may be useful for different experiential levels. As one participant put it: "...really these maps are useful during different phases of your familiarity with the building. So the first time you go into a building, the big map is really

useful. After you've been there a few times the big map will be less useful than it used to be... The smaller or the middle map might be more useful but once you've been there a few times the usefulness of that map falls off as well around."

For what concerns the room-level map, there was substantial disagreement on its utility. Some participants felt that all three scale levels are useful; for example, if "I walk in the door and I know where the front desk is and I know whether there would be chairs off to my right or my left or whatever I find, and wait for my name to be called". Others thought that the room-level map was '"kind of secondary", and that "the time and effort it takes to make that is less useful because the variables are too high", or that, due to the possible presence of movable objects of furniture, "when you have to get down to there, the map is out of date before you finish drawing". The way blind individuals negotiate a room-level space may also be different than for larger spaces (e.g., corridors, halls). In one participant's words: "From a practical point of view, I would walk into a room and stand at the door, listen to get a sense of the size of the room... I would go around the perimeter and come up and and just figure it out. I wouldn't take the time to use [the room-level map]".

*Universal map access*

Maps need to use symbols that must be understandable. Symbol standardization is an important issue; the need for using symbols and textures that are easy to interpret also emerged in the discussion. One participant pointed out that some symbols (e.g. building entrance) should be designed such they catch the user's attention right away, so that they are easy to find in the map. Also, given that these maps are at different scales, some additional information would need to be added to specify what kind of "view" is represented in the map. Some participants commented on the trade-off of using Braille character in lieu of symbols (e.g., to label an entrance). While Braille may take more space, it is easier to interpret – but only for those who know Braille. Indeed, it was noted that many of the potential users of these maps may not be able to read Braille.

## Discussion

Tactile maps are arguably a case of unexpressed potential. Many people believe they could be a valuable tool for pre-journey spatial learning, yet they are seldom used in practice. Part of the problem stems from very practical considerations: where to find these maps, when and how to explore them. It is possible that new refreshable display technology [10], or vibro-tactile display on commodity tablets [6], will alleviate some of this practical issues. Another major challenge is how to represent details at a wide range of levels. Lacking the ability to zoom in or out or to pan the map content (something that could theoretically be possible with refreshable or vibro-tactile display), multiple embossed maps at different scales are necessary to "see the tree and the forest". Our focus group was designed to gather feedback on this type of multi-scale tactile maps for indoor environments.

Perhaps not surprisingly, general consensus was often difficult to find on various themes. Some participants loved the idea of accessing indoor maps, other didn't see a lot of value in them. Some appreciated all three scale levels, others would just keep the structure-level map if it could contain more detail (note that, in the case of the building considered in our maps, this would be impossible to achieve due to the constraint imposed by tactile sensing resolution). This may again be driven by very practical considerations: having to manage multiple sheets of embossed paper in order to access different levels of detail for the same place is cumbersome. The room-level map received the most discordant comments. Given the wide variety of content that can be found in a room (e.g., table and chair vs. cubicles and desks vs. bathroom stalls and appliances), it may be impossible to generalize an assessment of the value of a map at this scale level from a single example.

## Conclusion

With the availability of technology to support automatic generation of indoors tactile maps, questions remains on how to best represent spatial layouts and space elements at an appropriate scale, and whether the use of multiple scale levels could be beneficial for pre-journey learning without sight. We conducted a focus group in order to obtain general insight on the perceived utility of multi-scale tactile maps of interiors. The natural sequel to this focus group would be to experiment with the use of maps at one or more scale levels before actual exploration of an unfamiliar building. While the utility of pre-journey learning using tactile maps or other spatial descriptions has been demonstrated before, these experiments will evaluate whether access to spatial information at multiple scale levels before exploration could lead to increased spatial awareness, more efficient wayfinding, and a more positive overall travel experience.

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